FINAL REPORT

FUNDAMENTAL DYNAMICS OF OCEAN STRUCTURES

Oregon State University
Office of Naval Research
University Research Initiative
(OSU-ONR-URI)

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submitted to
Office of Naval Research
Ocean Engineering Division
Dr. Steven Ramberg, Director

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March 28, 1995

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Enclosed are 12 copies of the final report on the Fundamental Dynamics of Ocean Structures prepared for the Office of Naval Research under the University Research Initiative.

Sincerely,

R T Hudspeth

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c.c OSU Business Affairs
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INTRODUCTION/BACKGROUND

Before being awarded the OSU-ONR-URI in 1986, the Ocean Engineering Program at Oregon State University was a graduate program in the Department of Civil Engineering centered around a core of five engineering faculty and a large-scale wave channel located at the O. H. Hinsdale - Wave Research Laboratory (OHH-WRL). Prior to 1986, the only Ocean Engineering professor receiving ONR funding was Prof. J. H. Nath in the Department of Civil Engineering. Interdisciplinary research, however, had been successfully conducted for over a decade with faculty in the Departments of Civil Engineering and Mathematics and in the College of Oceanography. These previous interdisciplinary research efforts left in a core of faculty with much needed and valuable experience in the special needs and requirements necessary to conduct interdisciplinary research at the level required to meet the goals and objectives of the OSU-ONR-URI.

At the time the OSU-ONR-URI proposal was being prepared, plans were already underway to relocate a small wave basin from Graf Hall on the campus of OSU to a new building being designed for the O. H. Hinsdale - Wave Research Laboratory. The OSU-ONR-URI funding made it possible to expand the dimensions of this wave basin as well as to upgrade the directional wavemaker for this basin. Funding for a unique circular wave basin capable of generating a variety of spiral waves was included in the OSU-ONR-URI proposal. A dynamic tow carriage for the existing 2-D wave channel was proposed.

The Ocean Engineering Program had a 16 year record of attracting high caliber U.S. graduate students and had been training and educating approximately 10 - 15 graduate students per year. A core curriculum in Ocean Engineering had been developed for a Masters of Ocean Engineering degree (MOcE) which requires a year of advanced calculus and a written thesis. Most of these theses were the result of funded research projects and were published in refereed journals. This history of successfully using Masters students on funded research projects made it possible for the OSU interdisciplinary team to meet the OSU-ONR-URI requirement for training and educating U.S. students.

This history of a successful interdisciplinary Ocean Engineering Program at OSU made it possible to propose and to successfully meet the four most important goals of the OSU-ONR-URI:

1) Conduct high risk research with a large interdisciplinary team

2) Acquire state-of-the-art instrumentation

3) Train and educate U. S. graduates

4) Transfer the technology from the research to Navy and DOD laboratories

SUMMARY OF SCIENCE ACHIEVED

Task 1.1 Dynamics of Rigid Bodies

Critical values of K: The identification of the value of the Keulegan-Carpenter parameter $K \approx 11.4$ makes it possible to identify data where the viscous effects (drag force component) are equal to the diffraction-radiation effects (inertia force component). This is essential for developing and for verifying experimentally any *unified field theory*. This *critical* value of K makes it possible to explain the following two phenomena: *1)* the simultaneous peak and trough in plots of C_m & C_d versus K; and *2)* the occurrence of stable transverse lift forces due to the shedding of a single eddy during exactly one-half of a wave period. This critical value of K was verified using three very different sets of laboratory data. Future experiments now must concentrate on filling the void in the data base where large values of the Reynolds parameter are needed when the Keulegan-Carpenter parameter $K \approx 11.4$.

Coupled Diffraction-Radiation Eigenseries Expansion: The completely coupled eigenseries solution plus the revised definitions for added mass and radiation damping coefficients reduced the CPU time required to compute solutions and eliminated unbounded values computed by previous definitions for hydrodynamic coefficients. The completely coupled solution revised earlier conclusions that were incorrect as a result of the truncation of trial function series used in the Rayleigh-Ritz methods.

Transforming irregular points to integrable singularities: The weak singularity exhibited by the irregular points may be removed to integrable singularities in order to eliminate the possibility of confusing these weak singularities with chaotic behavior in numerical algorithms. The elimination of this weak singularity by transforming the kinematic boundary condition is effective for Stokes' perturbation expansions. Elimination by conformal mapping of the physical domain to the unit disk and numerically solving a Fredholm integral equation on this unit disk requires inverting Jacobian elliptic integrals. This inversion requires contour integrals which are presently not known and requires further research.

Shallow water nonlinear waves: A nonlinear wave equation was developed modeling the evolution in time of shallow water waves over a variable topography. The usual assumptions of a perfect fluid and an irrotational flow were not made so that the resulting model equation was dissipative due to the presence of a viscous boundary layer at the bottom. The well-posedness of the Cauchy problem for classical solutions of this equation was addressed. In particular, it was established by means of various energy estimates and Sobolev space embeddings that a long time classical *(C^2)* solution to the Cauchy problem exists and is unique provided the initial data are small enough. An asymptotic result for the dependence of the lifespan of classical solutions upon the size of the initial data was given. Finally, a few results of an analytical nature (e.g., explicit computation of lifespans) were given for the model equation in one dimension in order to obtain useful parameters for experimental validation of the nonlinear wave model. Numerical results displayed the propagation of the nonlinear wave

in one and two spatial dimensions, and a comparison was made with the waves described by the familiar linear wave equation. General existence principles for systems of nonlinear differential equations of the form $y^{(\kappa)} = f\,(x,y,\ldots,y^{(\kappa-1)})$ subject to appropriate affine or nonlinear boundary data were established. When $f(\bullet)$ is continuous, classical solutions were found; and when $f(\bullet)$ is a Carathéodory function, solutions in appropriate Sobolev spaces were found.

Topological transversality: Existence principles of a *fixed point type* were developed which follow from the topological transversality theorem and the nonlinear alternative for fixed points. Existence principles of a *coincidence type* were given based on extensions of the topological transversality theorem and the nonlinear alternative to a coincidence setting. These existence principles of *coincidence type* avoid degree and coincidence degree considerations and simplify the entire theoretical development. Both classical and Carathéodory problems are treated simultaneously in a classical setting. This is accomplished by recasting the boundary value problem as an equivalent integral equation and by applying the topological methods to the integral equations. Despite the fact that Sobolev spaces are not used in the existence arguments, once a solution is known to exist it is automatically seen to lie in the appropriate Sobolev space.

Task 1.2 Dynamics of Highly Deformable Bodies

A new method to predict the transient and nonlinear interactions of highly-deformable bodies with large waves has been developed. A boundary element model of the fluid was coupled iteratively with a finite element model of the membrane in an implicit setting for the prediction of transient responses. The use of an implicit scheme for both the fluid model and the structure model will lead to much greater computational efficiency than has been previously possible with explicit schemes.

For the first time, the transient wrinkling of viscoelastic and hyperelastic membranes was analyzed numerically. A new *wrinkling* element was developed for a nonlinear finite element model of a viscoelastic membrane.

The model will permit designers to determine the effectiveness of fluid-filled membranes as engineering structures; i.e., temporary, rapidly-deployable floating breakwaters; semipermanent enhancement of existing fixed breakwaters; and bladder barges or storage depots.

Frequency domain models of inflated mattresses and float-tensioned membrane structures have been validated experimentally and demonstrate the utility of such structures for partial wave protection in short term applications.

Task 1.3 Dynamics of Cables and Mooring Systems

A new technique for the nonlinear time-domain analysis of long curved cables has been developed which is both computationally efficient and robust for typical ocean cable applications.

Comparisons of the new method to experimental results and to other numerical results show the new method to compare favorably both in accuracy and efficiency.

New simulation techniques have been developed to include nonlinear material effect (e.g. torsion and viscoelasticity) and fluid loading effects (e.g. strumming) into the dynamic analysis of complex mooring and cable-laying problems. Furthermore, analytical and numerical investigations indicate significant effects of drag stiffening on cable vibration for slack cables in strong currents; however, experimental validation is needed.

Task 2.1 Wave Groupiness

The Hilbert transform was shown to be an exact low-pass filter that is capable of isolating wave groups without incorporating the distortions that plague both the *SIWEH & LVTS* methods. Groupiness factors derived from either *SIWEH or LVTS* were shown to not be measures of wave groupiness; but rather measures of the distortions introduced by the low pass filters used. All previously published wave group parameters were correlated; which implies that none of these wave group parameters are unique. Because a wave groupiness parameter defined by the Hilbert transform is distortionless, a groupiness factor defined by the Hilbert transform is recommended for analyzing wave groups along with a Poisson counter defined as an envelope exceedence parameter. The mean run length that correlates with the spectral shape was shown to not be an appropriate measure of wave groups. These groupiness concepts have been successfully extended other simulations such as climatology and appear to be very robust techniques for including groupiness effects in both analyses and design.

Task 2.2 Effects of Structures on Edge Wave Dynamics

Longshore currents are the dominant mean flow in the nearshore and are responsible for the majority of the net sediment transport in the littoral zone. Dynamics have always been modelled simply with forcing derived from the xy component of wave radiation stress, dissipation by bottom friction and horizontal mixing based on eddy diffusion arising basically from wave orbits.

The presence of shear waves has two major effects. First, the magnitudes of longshore currents are found to be considerably more variable than previously thought, with shear wave oscillations having time scales of the order of five minutes (on ocean beaches) and magnitudes on the order of the mean current. Second, the cross-shore profile of the current can be significantly mixed by the presence of shear waves through a wave eddy flux. Since the presence of the shear wave component of mixing depends on different dynamics than are expressed in traditional mixing parameterizations, shear waves represent an important missing ingredient in models of mean longshore currents.

Field tests of the theory are complicated by the presence of a variety of low frequency energy that is forced by incident wave groups. The ability to study the process of shear wave

generation in the circular wave tank under monochromatic forcing has allowed a much clearer view of the important dynamics.

Task 3.1 Dynamic Tow Carriage

A design for a dynamic tow carriage for the 2-D wave channel at the OHH-WRL has been completed. The acquisition of this state-of-the-art system did not occur due to a reduction in funds for OSU-ONR-URI. Nevertheless, the completed design will be submitted for alternative funding.

A state-of-the-art (SOA) digital image capture system was acquired. This system will be used to monitor chaotic motion of a submerged, moored structure subject to surface wave excitation. This SOA system makes it possible to record non-interfering position measurements at the OHH-WRL.

Task 3.2 Directional Spectral Wavemaker

A state-of-the-art (SOA) directional wavemaker has been acquired for the OHH-WRL. This SOA directional wavemaker has direct-digital control; high-torque AC electric motion power units; lead screw drives connected to the edge of each wave board; shape and displacement compensating seals between wave boards; and active-reflected wave cancellation. This technology leap will carry OSU and the USA into the twenty-first century with a powerful laboratory capable of validating the theoretical models used to analyze the fundamental dynamics of ocean structures and near shore processes. SOA wave gauge instrumentation was developed and used successfully to measure beach profiles.

Task 3.3 Spiral Wavemaker

The physical modelling of waves, currents, sediment transport and shoreline changes in the near shore have typically been conducted in rectangular wave basins. These basins are subject to end wall effects which induce artificial changes both in the wave field and in the circulation and sediment transport patterns. The circular wave basin with a spiral wavemaker eliminates many of these problems. The first random spiral wavemaker in the world was designed and constructed at the OHH-WRL. Based on experience gained with this first random spiral wavemaker, a large scale wavemaker was designed. To demonstrate the utility of the circular wave basin as research tool, several specific problems were examined.

Task 2.2 originally proposed a methodology for studying edge waves in a circular basin. During the OSU-ONR-URI, a new and important type of wave, a shear wave, was discovered from field data. Because the circular wave basin was the only existing facility which would allow an experimental verification of these waves, the Task was modified. The circular wave basin was used to examine longshore currents in simple periodic and random waves. Wave-

induced circulation around nearshore structures was also examined. Future projects will study sediment transport and shoreline evolution to remove the problems associated with end effects. Even the beach profile itself may necessitate three-dimensional modeling. Recent experimental results from wave channel experiments suggest that beach profile responses for beaches that front structures are not modeled well in two-dimensional wave channels.

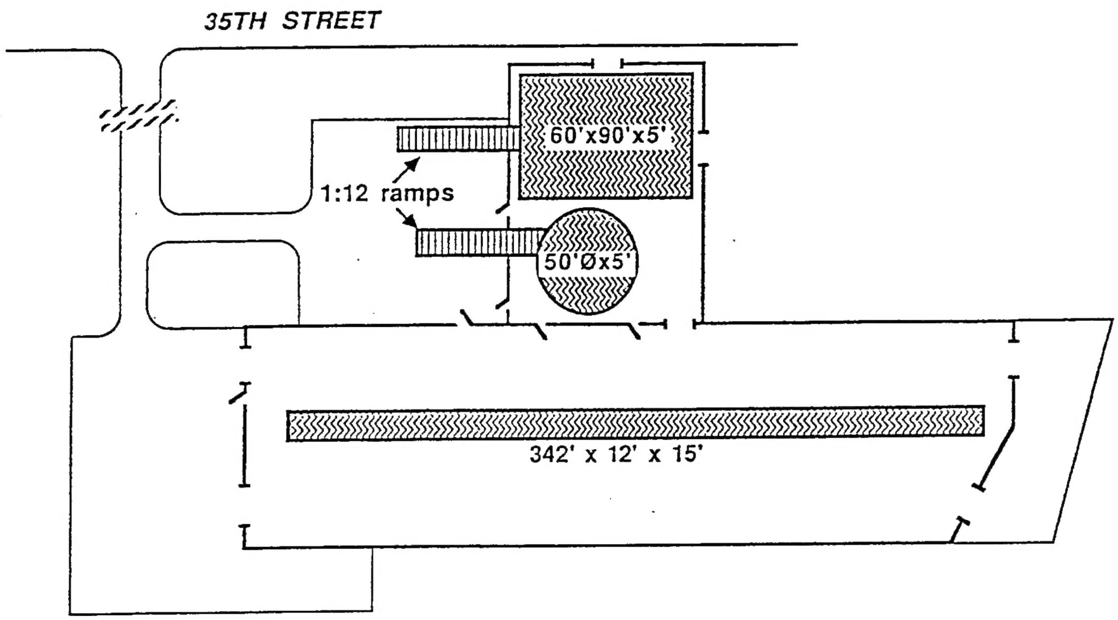
Task 3.4 Circulation Dynamics in a Bounded Domain

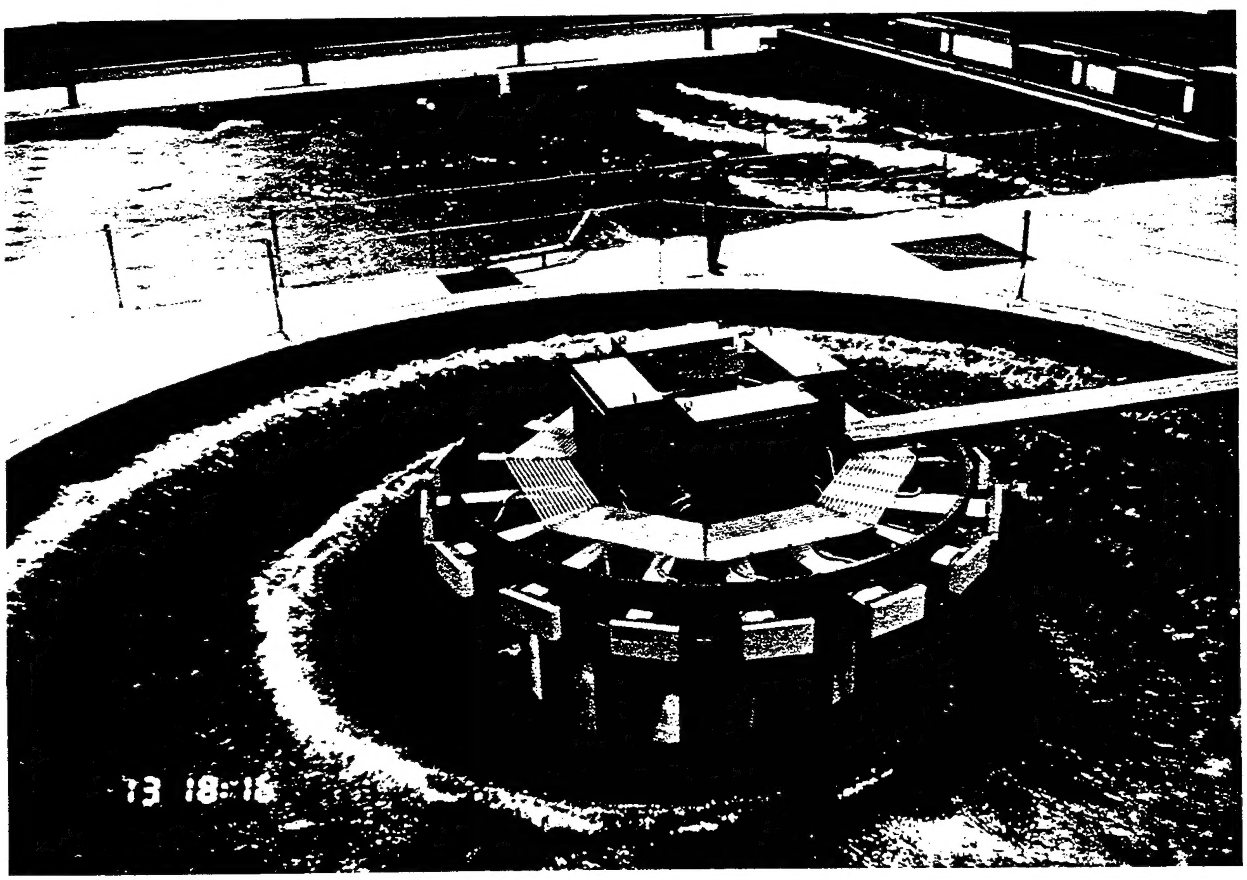
The weakly nonlinear boundary value problem for a generic planar wavemaker was solved correctly to second-order in the Stokes perturbation expansion for the first time. This complete solution includes both time-dependent and time-independent terms. The time-independent terms modified significantly previously incorrect interpretations about the weakly nonlinear wavemaker boundary value problem. Two important conclusions regarding the effects of the first-order eigenseries solution on the second-order solutions also modified previous incorrect conclusions regarding the second-order solutions.

First, the first-order evanescent eigenseries may not be neglected when computing the amplitude of the second-order free-wave as is commonly assumed in second-order solutions. Second, the second-order eigenseries that include the first-order eigenseries do not converge for all planar wavemaker geometries. This lack of convergence for some planar wavemaker geometries has not been previously reported.

The complete second-order eigenseries solution contains time-independent terms which significantly affect previous conclusions regarding mean motions in wave flumes. The non-zero mean motion due to the weakly nonlinear kinematic boundary condition on the wavemaker exists for both piston and hinged wavemakers of variable-draft when the kinematic boundary condition is expanded in a Maclaurin series about the mean wavemaker position. This forcing is non-zero only for a hinged wavemaker when applied at the instantaneous location of the planar wavemaker. The time-independent forcing on the mean free-surface boundary is evanescent in x. By including the time-independent terms in the complete solution correct to second-order, the mean horizontal momentum per unit area is equal to zero by both the Eulerian and Lagrangian methods. This is because the time-independent potentials in the complete solution generate mean horizontal velocities that are equal in magnitude but opposite in direction to the Stokes drift. This mean Eulerian return flow has been computed previously from a kinematic conservation of mass flux principle.

MAJOR FACILITIES ACQUIRED
O. H. HINSDALE WAVE RESEARCH LABORATORY





The original laboratory facilities at the O. H. Hinsdale Wave Research Laboratory (OHH-WRL) at Oregon State University were constructed in 1973 from funds donated by Mr. Howard Hinsdale with additional funding from industry and research agencies. The main feature was a large wave channel, 342 ft long, 12 ft wide and 15 ft deep. A hinged-flap waveboard, hydraulically driven by direct-digital control, generates random and monochromatic waves up to 5 ft high. This is the largest university owned and operated wave channel in the world for validating theoretical wave models using large scale experiments with minimum Reynolds number distortion. Research at the laboratory has focused on fundamental wave mechanics and the analysis and design of ocean and coastal structures.

The OSU-ONR-URI made it possible to expand the facilities to include a new 37,500 ft^2 environmental enclosure for the existing wave channel; a 12,500 ft^2 East Wing enclosure with a new rectangular wave basin for directional spectrum studies; and a new circular wave basin with random spiral wave generation capabilities. An 1,875 ft^2 elevated control room provides centralized control and data acquisition.

The rectangular wave basin is 87 ft long, 60 ft wide and 5 ft deep with a segmented, directional spectral wave generator. The 2 ft wide wave generator segments are powered by individual AC motors and are driven by ball screws at the edge of each segment, providing a continuous wave front with minimum parasitic waves. Active reflected wave absorption is provided by the control system and maximum wave heights approaching 2.5 ft are generated at a spectral peak period of 2-3 seconds. Two modules of 15 segments each are located along the 60 ft side of the basin. Superimposing waves of various frequencies, heights, and directions provides the ability to produce chaotic wave environments common to deep ocean storm sites.

The unique circular wave basin is 50 ft in diameter and 5 ft deep with a segmented, random wave generator 10.8 ft in diameter. Sixteen wave generator segments are edge driven, each powered by AC motors with ball screw drives producing waves up to 2.2 feet high. Active reflected wave absorption is provided by the control system. The circular wavemaker generates spiral shaped wave fronts. These spiral waves drive littoral processes and two different wave frequencies may be combined to induce edge waves. No other random segmented spiral wave generators are known to exist in the world. Finally, a radial arm tow carriage is to be added with future funding to allow towing of model vessels in circular trajectories to simulate an endless tank.

Direct digital control of all three wave generators is provided by a VAX server 3400 and two local VAX stations 3100. Optical communication links connect the VAX stations to the wave generators and a 64 channel digital data acquisition system.

FUTURE DIRECTIONS

Ronald B. Guenther

The interaction between the flow and the bottom must be further explored in the case of chaotic or turbulent flows. In the case of chaotic behavior, will only statistical methods be applicable or are there other methods for describing the long term behavior of chaotic, dynamical systems?

The topological methods developed must be refined to give local as well as global information. At the present time, they give global existence results in differentiability classes; they give intervals in which solutions exist; periodicity of solutions to nonlinear differential equations; but no information about how chaotic the solutions may be. Topological methods will give new insights into chaotic behavior and offer an alternative to the Melnikov method.

Typical derivations of the equations for shallow water waves assume that the free surface of the water is described by a function of time and of two horizontal spatial coordinates. Such a description precludes breaking waves. As an alternative, the interface between water and air may be represented by the level set of a function $u(x,y,z,t)$; that is by a set of points (x,y,z) such that $u(x,y,z,t) = c$, for some constant c. Clearly, this set of points can change position as t varies allowing consideration of the motion of the interface.

Capillary waves depend on the surface tension and the mean curvature of the air-water interface. Extensions to more general inviscid and viscous flows must be pursued.

Robert A. Holman

Present results demonstrate convincingly the process of shear wave instability and strong mean longshore currents. A set of experiments is required to complete the documentation of the mechanism in several areas. Comparisons of the predicted growth rates with observed energies must be completed. Without friction, these are not directly connected. However, if broad-banded dissipation is assumed, then the maximum observed energy should equate to the frequency of fastest growth.

The role of shear waves in the cross-shore mixing of the mean longshore current jet as shown in the energy equation must be investigated. Because the shear wave mechanism has different dependencies than the eddy mixing model, traditional models can be in error, depending on the nature of the beach topography. For example, the high shears of longshore current on a barred beach suggest that shear wave mixing may play a much more important role than expected, and may explain field observations of the anomalous strength of longshore currents in the trough of barred beaches.

Finally, shear wave dynamics and consequences should be included in nearshore circulation models.

Robert T. Hudspeth

The high risk research on the chaos of nonlinear dynamical systems provided a foundation for utilizing the Wiggins-Holmes extension of the Melnikov method to search for chaos in free-surface boundary problems. The need to determine the canonical variables for a Lagrangian density that includes boundaries other than the free-surface has been identified for further research. Also identified for future research is the need to construct contact transformations for both the canonical variables and the Hamiltonian density which is not the sum of kinetic and potential energy as, for example, in the case of free-surface gravity wave Lagrangian densities.

Transforming the irregular points to the unit disk requires inverting the Jacobian elliptical integral by the calculus of residues using contours that are presently not known and requires future research.

John W. Leonard

Most viscoelastic materials are only (approximately) linear over a narrow range of deformations and a more general nonlinear representation which subsumes the linear model is required. Furthermore, any time-dependent material model must reasonably handle the frequency content of the loading. A formalism (e.g., the *complex modulus*) that incorporates higher frequency loading is required. All of these capabilities must be consistent with an ability to describe the membrane response under certain stress states that result in a *wrinkled* condition.

A new strategy for the active control of tension structures must be developed. The control algorithm incorporates nonlinearities and uncertainties and is implemented in a decentralized manner. Control forces are generated for and sensor information obtained from subsystems of the structure. The decentralized approach is more reliable since loss of sensor information only effects a certain portion of the structure.

Problems of fluid-structure interaction, ranging from scale model wave tank tests to monitoring of full scale prototypes, require evaluation of underwater structural displacements. Very few robust, non-invasive displacement measurement systems exist to fulfill this need.

William G. McDougal

The random spiral wavemaker-circular basin is a unique facility that may be used to examine edge waves, sediment transport, beach profiles, shear waves, longshore currents, circulation around nearshore structures, and the influence of random waves.

Charles K. Sollitt

The O. H. Hinsdale-Wave Research Laboratory provides a unique facility for examining directional aspects of wave-structure interaction; experimental validation of second-order frequency domain models for poro-elastic rubble structures; and transportable membrane structures in three dimensional seas.

SUMMARY AND ACKNOWLEDGEMENTS

During 1986-1991, OSU received $7,616,571 from ONR under the URI for the nine research tasks in the three focus areas listed in Table 1.

FOCUS AREA #1 COMPLIANT OCEAN STRUCTURES	FOCUS AREA #2 NEARSHORE STRUCTURES & CIRCULATION DYNAMICS	FOCUS AREA #3 STATE-of-the-ART INSTRUMENTATION
TASK #1.1 DYN of SOLID BODIES	TASK #2.1 WAVE GROUPINESS	TASK #3.1 DYNAMIC TOW CARRIAGE
TASK #1.2 DYN DEFORMABLE BODIES	TASK #2.2 EDGE WAVE DYNAMICS	TASK #3.2 DIRECTIONAL WAVEMAKER
TASK #1.3 DYN of CABLES & MOORING SYSTEMS		TASK #3.3 SPIRAL WAVEMAKER
		TASK #3.4 CIRCULATION DYN in WAVE BASINS

Table 1. Summary of Focus Areas and Tasks

The distribution of the expenses for these funds is shown in Figure 1.

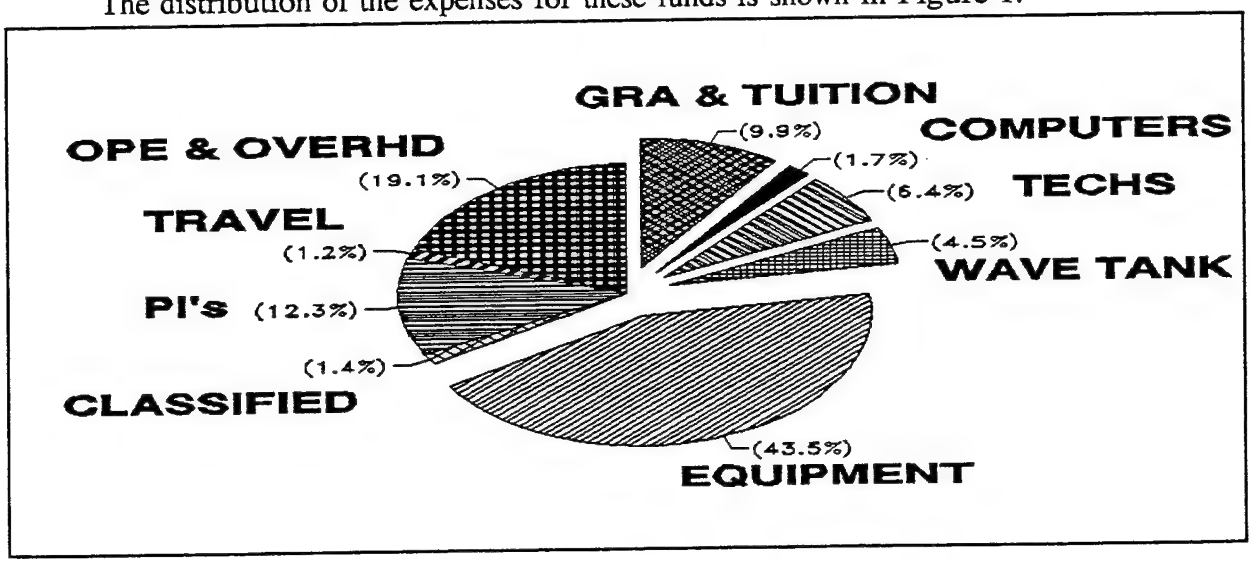


Figure 1. Distribution of expenses for OSU-ONR-URI funds

Only *19%* of the total funds were spent on *Other Personnel Expenses (OPE)* and *Overhead* because the equipment purchases were exempt from these charges. Approximately *43.5%* of the total funds were used to acquire *state-of-the-art instrumentation* for the O.H. Hinsdale Wave Research Laboratory. These acquisitions for the OHH-WRL make this laboratory one of the most comprehensive wave research laboratories anywhere.

Figure 1 demonstrates that approximately *66%* of the total funds (or approximately 81.5% of the funds left after OPE & Overhead expenses) were used for the following: *1)* to acquire state-of-the-art instrumentation; *2)* to acquire experimental data in the OHH-WRL; and *3)* to fund U. S. graduate students. Only approximately *12.3%* of the total funds were used to support PI's in comparison with *11.6%* of the total funds used to support U. S. graduate students and to provide them with computers. Only *1.2%* of the total funds were used to support travel.

The interdisciplinary nature of the OSU-ONR-URI is illustrated by the distribution of PI support by Department or College shown in Figure 2.

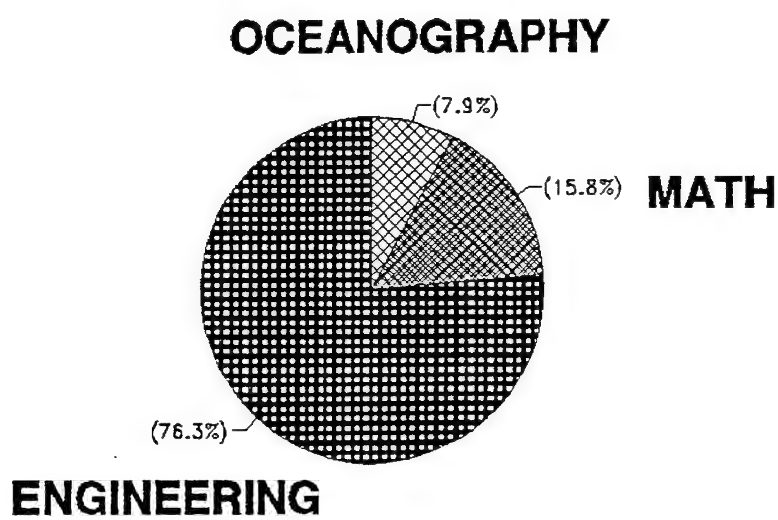


Figure 2. Distribution of PI support by department and colleges

The distribution by the Tasks listed in Table 1 of the total PI support for the department of mathematics and the colleges of engineering and oceanography is illustrated in Figure 3.

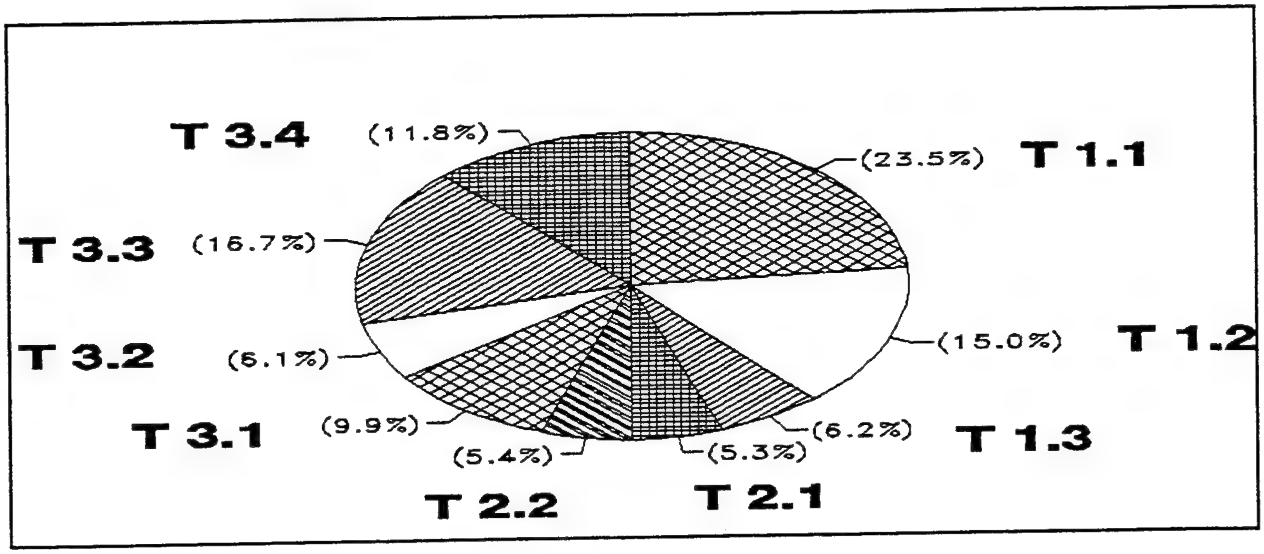


Figure 3. Distribution of PI support by the tasks listed in Table 1

The PI funds for the College of Oceanography supported Dr. R. A. Holman. The PI funds for the Department of Mathematics supported 8 faculty with the majority of the support going to Dr. R. B. Guenther. Finally, the distribution of PI support in the College of Engineering only is illustrated in Figure 4.

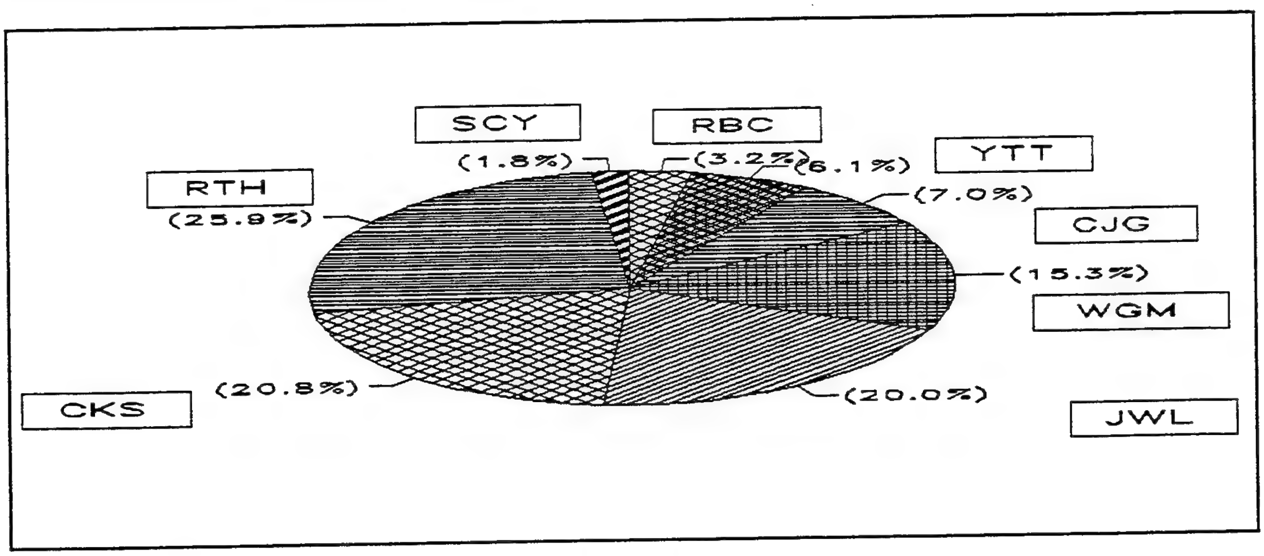


Figure 4 Distribution of PI support for the college of engineering

Legend for Figure 4: ***RTH:*** R.T. Hudspeth; ***SCY:*** S.C. Yim; ***RBC:*** R.B. Chiou; ***YTT:*** Y.T. Tsai; ***CJG:*** C.J. Garrison; ***WGM:*** W.G. McDougal; ***JWL:*** J.W. Leonard; ***CKS:*** C.K. Sollitt

The number of graduate/undergraduate degrees awarded to date to U.S. students funded by the OSU-ONR-URI is summarized by college and department in Table 2. A list of all U.S. students funded under the OSU-ONR-URI with their destinations is given in Appendix **B**.

Degree	Engineering	Math	Oceanography
Ph.D.	2(2)	1(1)	
M.S.	8(4)	5	(1)
B.S.	9(1)		

Table 2. Summary of degrees funded by the OSU-ONR-URI

Legend for Table 2: (•) in progress

The publications to date under the OSU-ONR-URI are summarized in Table 3. Complete citations for the publications summarized in Table 3 are listed by year in Appendix **C**.

Year	P	PS	PI	R	C	IC
1986	2					
1987	5				4	
1988	5				6	2
1989	10			2	6	2
1990	17				6	2
1991	17	9	13		8	
1992	1				1	

Table 3. Summary of publications completed under the OSU-ONR-URI

Legend for Table 3: **P** Paper **PS** Paper Submitted **PI** Paper in Progress **R** Report **C** Conference **IC** Invited Conference

The *technology transfer* accomplished under the OSU-ONR-URI is summarized by activity in Table 4. A listing of the personnel involved in these *technology transfer* activities is given in Appendix **D**.

Year	IPA	OHH-WRL	DOD Funding	Other Tech Transfer
1987	1	0	0	0
1988	0	1	3	0
1989	3	1	4	2
1990	2	2	2	3
1991	0	4	2	0

Table 4. Summary of OSU-ONR-URI technology transfer

ACKNOWLEDGEMENT:

The OSU-ONR-URI has benefitted significantly from the advice, constructive comments, and loyal support of the OSU-ONR-URI Advisory Committee. The written critiques and verbal comments provided by these members following the annual Advisory Committee meetings were responsible for many mid-course corrections that redirected some of the research. The time and energy donated by these members is gratefully acknowledged and deeply appreciated.

OSU-ONR-URI ADVISORY COMMITTEE

1987

Dr. Jared Black, UNOCAL Science and Technical Division, Brea, CA
Dr. E. D. Cokelet, NOAA/PMEL Seattle, WA
Capt. D. R. Wells, NAVFAC, Arlington, VA
Mr. R. N. Cordy, Naval Civil Engineering Laboratory, Port Hueneme, CA
Mr. Walt Frick, U.S. EPA, Hatfield Marine Science Center, Newport, OR
Dr. J. R. Houston, Waterways Experiment Station, Vicksburg, MS
Dr. N. E. Huang, NASA Goddard Space Flight Center, Greenbelt, MD
Mr. Walter Lincoln, U. S. Coast Guard Research and Development Center, Groton, CT
Mr. Ed Linsenmeyer, Naval Coastal Systems Center, Panama City, FL
Dr. S. C. Liu, National Science Foundation, Washington, D.C.
Dr. Stuart F. Pawsey, PMB Systems Engineering, Inc.
Dr. Paul Ristin, David Taylor Naval Ship Research and Development Center, Bethesda, MD
Mr. Charles Smith, U. S. Dept. of the Interior, Minerals Management Service, Reston, VA

Dr. Ming-Yang Su, Naval Ocean Research and Development Center, NSTL, MS
Dr. Chung Chu Teng, NOAA Data Buoy Center, NSTL, MS
Dr. Henry Wang, Navy Research Lab, Washington, D.C.

1988

Dr. D. J. Baumgartner, Hatfield Marine Science Center, Newport, OR
Dr. Jared Black, UNOCAL Science and Technical Division, Brea, CA
Dr. E. D. Cokelet, NOAA/PMEL Seattle, WA
Mr. Andrew Del Collo, NAVFAC ENG COM HQ, Arlington, VA
Mr. R. N. Cordy, Naval Civil Engineering Laboratory, Port Hueneme, CA
Dr. J. R. Houston, Waterways Experiment Station, Vicksburg, MS
Dr. N. E. Huang, NASA Goddard Space Flight Center, Greenbelt, MD
Mr. Walter Lincoln, U. S. Coast Guard Research and Development Center, Groton, CT
Dr. Ed Linsenmeyer, Naval Coastal Systems Center, Panama City, FL
Dr. S. C. Liu, National Science Foundation, Washington, D.C.
Mr. Charles Smith, U. S. Dept of the Interior, Minerals Management Service, Reston, VA
Dr. Ming-Yang Su, Naval Ocean Research and Development Center, NSTL, MS
Dr. Chung Chu Teng, NOAA Data Buoy Center, NSTL, MS
Dr. Henry Wang, Navy Research Lab, Washington, D.C.

1989

Dr. Steve Allen, U. S. Coast Guard Research and Development Center, Groton, CT
Dr. Jared Black, UNOCAL Science and Technical Division, Brea, CA
Dr. E. D. Cokelet, NOAA/PMEL Seattle, WA
Mr. Andrew Del Collo, NAVFAC ENG COM HQ, Arlington, VA
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Dr. Ed Linsenmeyer, Naval Coastal Systems Center, Panama City, FL
Dr. Martin Miller, Waterways Experiment Station, Vicksburg, MS
Dr. Ming-Yang Su, Naval Ocean Research and Development Center, NSTL, MS
Dr. Chung Chu Teng, NOAA Data Buoy Center, NSTL, MS
Dr. Henry Wang, Navy Research Lab, Washington, D.C.

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Mr. Walter Lincoln, U. S. Coast Guard Research and Development Center, Groton, CT
Mr. David Shields, Naval Civil Engineering Laboratory, Port Hueneme, CA

Mr. Charles Smith, U. S. Dept. of the Interior, Minerals Management Service, Reston, VA
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1. Reference: DoD Directive 5230.24, Distribution Statements on Technical Documents, 18 Mar 87.

2. The Defense Technical Information Center received the enclosed report (referenced below) which is not marked in accordance with the above reference.

FINAL REPORT
N00014-86-K-0687
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3. We request the appropriate distribution statement be assigned and the report returned to DTIC within 5 working days.

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DEPUTY DIRECTOR
CORPORATE PROGRAMS OFFICE

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19 SEP 1995

(Date Statement Assigned)